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IV.

An Account of the Nebula in Andromeda.

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(Read before the Academy, March 7th, 1848.)

OF the four thousand nebulæ which have been recognized, that which forms the subject of the present account is the only one the discovery of which preceded the invention of the telescope. The evidence which history affords of its having been noticed prior to the year 1612 is derived through Ismael Bouillaud, a writer of the seventeenth century, author of the *Philolaica Astronomica*, and, among other astronomical treatises, of one entitled, *De Nebulosâ in Andromeda Cinguli Parte Boreâ ante Biennium iterum Ortû*; containing an ancient catalogue of stars, with charts of the constellations, on which the nebula is represented of an oval form, and according to Le Gentil, “fait un angle avec le circle de longitude.” By comparing the positions of the stars in this catalogue with modern determinations, the latter found that the date of its construction was towards the close of the tenth century. As there seems to be no reason for doubting the authenticity of this production, it is probable that the great nebula in Andromeda was recognized at least six hundred years before the invention of the telescope.

Its appearance in 1612 is described with some care by Simon

Marius in the Preface to his *Mundus Jovialis*. It was then visible to the naked eye, and appeared through the telescope to be composed of rays of light (*radii albicantes*), increasing in brightness as they approached the centre, which was marked by a dull, pale light, — “in centro est lumen obtusum et pallidum.” Its diameter was a quarter of a degree, and it resembled the light of a candle, at some distance, shining through horn. Its appearance is also compared to that of the comet observed by Tycho Brahe in 1586.* From some of his remarks, it seems that this author regarded the nebula as an object of extraordinary interest; and he expresses his astonishment at its having been unnoticed by Tycho when observing the stars in its neighbourhood.

No further intimation of its having been seen is to be found until 1664. In that year, the appearance of a comet having directed the attention of astronomers to the region in the vicinity of the nebula, it was again discovered, and has not since been lost sight of.

In the treatise of Ismael Bouillaud before referred to, which was published in 1667, the author maintains, from the fact of its not having been recorded either by Hipparchus, Tycho, or Bayer, as well as from what he had himself observed, that this nebula is subject to periodical variations in brightness; an opinion which was maintained by many during the succeeding century.

In 1740, Cassini defines its figure as nearly triangular. Mairan, after stating that the description given by Simon Marius conformed to what he had himself observed in 1754, asserts that it is subject to changes. The same views are supported by Le Gentil in a memoir, *Sur les Étoiles Nebuleuses*. From a careful

* As there was no comet in 1586, that of 1585 is perhaps intended.

review of its past history, he concludes that the periodical variations of the nebula extend to its figure, as well as to its brightness. His grounds for this conclusion may be briefly stated as follows : —

1. The nebula is not found in any of the ancient catalogues.
2. It was visible to the naked eye in the year 995, and its form was then oval.
3. For more than six hundred years afterwards it was unnoticed.
4. The description given by Simon Marius of its appearance in 1662 does not accord, in an important particular, — that of exhibiting a central condensation, — with the observations of Le Gentil in 1750.
5. This condensation was not mentioned by Bouillaud in 1666, who records an evident change of brilliancy between 1664 and 1666.
6. Cassini, in 1740, represents its figure as triangular.
7. Mairan, in 1754, regards the representation of Simon Marius as essentially correct.
8. His own observations indicated a round figure, of uniform density throughout, in 1749 ; and an oval figure with a central condensation, in 1757–8.

Although expressing himself convinced, by the foregoing considerations, of the reality of a change, Le Gentil at the same time suggests that these phenomena may be, in part, at least, explained by referring them to the difference in the instrumental means employed by the several observers. His own telescopes were the common refractors, of from three to thirty feet in focal distance, in use before the invention of the achromatic object-glass, and were of course very inferior to instruments of a more recent date.

As all subsequent accounts of this nebula can, without violence,

be reconciled with its appearance at the present day, it may reasonably be concluded that the views of Le Gentil, with regard to its variability, are far from being supported by an amount of evidence adequate to such a conclusion. Messier, in 1771, remarks, that for fifteen years he had noticed no change in the nebula ; it always appeared to him bright at the centre, the light fading away insensibly towards both extremities, its figure resembling that of two cones with their bases opposed. In the *Philosophical Transactions* for 1785, it is thus described by Sir William Herschel.

“ It is undoubtedly the nearest of all the great nebulae ; its extent is about a degree and one half in length, and, in even one of the narrowest places, not less than sixteen minutes in breadth. The brightest part of it approaches to the resolvable nebulosity, and begins to show a faint red color ; which, from many observations on the color and magnitude of nebulae, I believe to be an indication that its distance in its colored parts does not exceed two thousand times the distance of Sirius.

“ There is a very considerable, broad, pretty faint, small nebula near it ; my sister discovered it, August 27th, 1783, with a Newtonian two-feet sweeper. It shows the same faint color with the great one, and is, no doubt, in the neighbourhood of it. It is not the 32d of the *Connaissance des Temps* ; which is a pretty large, round nebula, much condensed in the middle, and south-following the great one ; but this is about two thirds of a degree north-preceding it, in a line parallel to β and γ Andromedæ.”

In the same memoir from which the above extract is taken occurs the following passage.

“ But it is nevertheless very evident that the united lustre of millions of stars, such as I suppose the nebula in Andromeda to be, will reach our sight in the shape of a very small, faint nebulosity ; since the nebula of which I speak may easily be seen in a fine evening.”

It ought, perhaps, here to be observed, that the views of this illustrious astronomer, in later years, received some modification in respect to the nature of many of the nebulae.

The following is Sir John Herschel's description, in 1826.

“ At present it has not, indeed, a star, or any well-defined disk in its centre, but the brightness, which increases by a regular gradation from the circumference, suddenly acquires a great accession, so as to offer the appearance of a nipple as it were in the middle, of very small diameter (10" or 12"), but totally devoid of any distinct outline ; so that it is impossible to say precisely where the nucleus ends and the nebula begins.

“ Its nebulosity is of the most perfectly milky absolutely irresolvable kind, without the slightest tendency to that separation into flocculi above described in the nebula in Orion, nor is there any sort of appearance of the smallest star in the centre of the nipple. This nebula is oval, very bright, and of great magnitude, and altogether a most magnificent object.”

The following passage, occurring in another connection, may also be cited.

“ The great nebula in Andromeda may be, and not improbably is, optically nebulous, owing to the *smallness* of its constituent stars.”

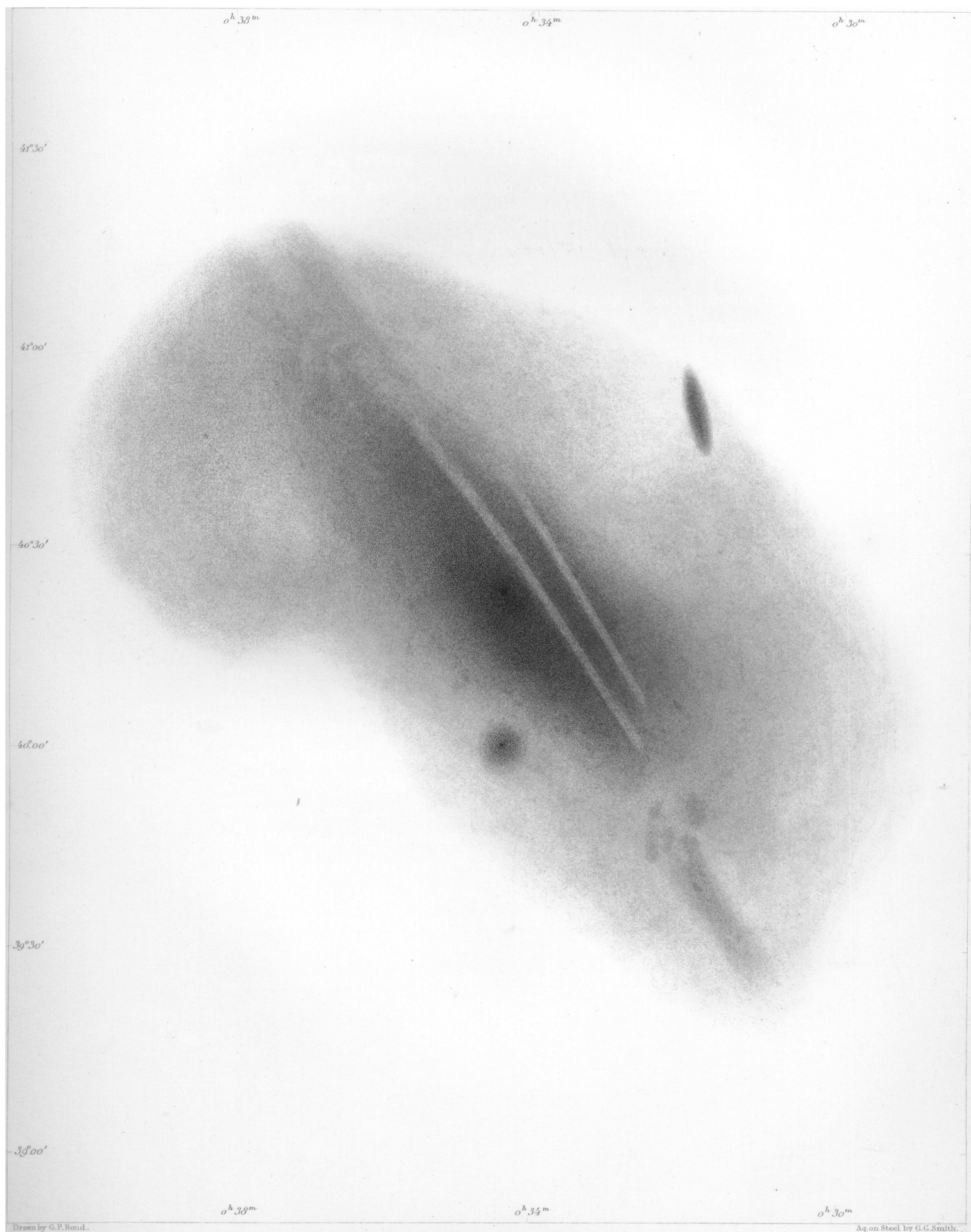
In 1836, Dr. Lamont, of Munich, observed it with a refractor of great capacity ; under a power of 1200, the diameter of the nucleus was about 7". His description accords with that of Sir John Herschel.

The mounting of the great refractor of the Cambridge Observatory having been completed in the beginning of July, 1847, an early opportunity was taken of directing it upon the nebula in Andromeda, as being an object of prominent interest ; and from that time, through the month of August, it was occasionally viewed, though without particular attention. The most con-

spicuous features were the sudden condensation of light at the centre into an almost starlike nucleus ; the vast number of stars, of every gradation of brilliancy, scattered over its surface, which yet had the undefinable, but still convincing, aspect of not being its components ; and, lastly, what appeared to be a sudden termination of the light on the side of the nebula preceding in right ascension.

But it was not until the beginning of the autumn that a careful examination was commenced of the regions of the nebula remote from the nucleus. On the 14th of September, a favorable opportunity offered for further investigation. By directing the attention to the preceding portion of the nebula, as it passed the centre of the field of view, it was evident that what had hitherto been regarded as its boundary in that direction was rather a sudden interruption of light, appearing like a narrow, dark band, in which the eye could detect no deviation from perfect straightness, stretching, in the direction of the axis of the nebula, entirely across the field of vision ; exterior to this, with respect to the axis, was another band or canal, closely resembling the former, but somewhat less distinct, of equal regularity, and so nearly parallel with it as to make it difficult to decide, by simple inspection, whether they were not perfectly so. What particularly commands admiration here is the regularity of structure displayed, — the uniform influence, made manifest to the senses, of the same law over an immensity of space of which the mind can form no adequate conception ; since the distance at which Sir William Herschel places this nebula requires that the length of the interior canal should not be estimated at less than twenty times the distance of Sirius from our system.

As a groundwork for the delineation of the principal features



THE GREAT NEBULA IN ANDROMEDA, 1847.

of this nebula, it was at first proposed to prepare, from micrometric measurements, a map of the principal stars involved in the light. But their great number,* and the consequent danger of confusion, having rendered this impracticable, the circle readings of the equatorial were resorted to for the determination of all the positions referred to in this memoir.

The extent of the region to be examined being from fifteen to twenty times larger than could be included within a single field of the telescope, the brightest portions, namely, from Dec. $39^{\circ} 40'$ to Dec. $41^{\circ} 10'$, were divided into eighteen sections, each comprising five minutes of declination, and extending in right ascension across the nebula. The telescope was clamped in declination at the middle of each zone, and the examination was commenced by moving the instrument with a quick motion in right ascension, which was found necessary in order to determine with any certainty the limit of light on either side of the axis. The nebula was then allowed to pass through the field by its diurnal motion, and the times recorded when the different gradations of light occupied the centre of the field, taking in each transit, for the standard of brilliancy, that portion of the axis intersected by the zone; the hour-circle was then read off, and the instrument set for a new series. The different zones were finally referred to a common unit of brightness, by a cross section from the nucleus to both extremities of the axis. In this manner an idea, though not a very accurate one, was obtained of the situation of the lines of equal brilliancy. The observations were then charted, so as to present them at a single view, accompanied by such remarks as had been recorded at the time at

* It is estimated that above fifteen hundred stars are visible with the full aperture of the object-glass within the limits of the nebula.

which they were made. The chart thus constructed was used as a guide in attempting the delineation of the nebula.

The figure which accompanies this memoir is necessarily on much too small a scale to admit of the introduction of minute details. Though prepared with care, in the manner just described, it must remain open to future correction. The chief source of error has been the difficulty of referring every portion to the same standard of brightness.

The observations generally were made under very favorable circumstances. In a large proportion, the altitude of the nebula exceeded seventy degrees; in more than one instance, its zenith distance was less than two degrees. Those nights only were employed in which the moon was absent, and the sky perfectly clear. The power usually employed was one hundred and three, with a field of twenty minutes. The following are the results of the examination to which the nebula has been subjected.

The nucleus is nearly centrally situated with respect to the general body of light, but perhaps nearest the side following in right ascension. Its appearance cannot be better described than by adopting the words of Sir John Herschel already quoted.

With high powers, minute stars are discerned on the borders of the nucleus, but it has thus far yielded no evidence of resolution. About fifty stars are visible in the same field with it; no other equal space occurs within the limits of the nebula containing so few.

The region south-preceding the nucleus is somewhat brighter than the opposite side; this has been noticed by Smyth; it is also so represented on Harding's Atlas, whether by accident or designedly does not appear. The axis of the nebula, which is for the most part strongly marked, particularly in its south-preceding half,

lies in a great circle passing near the nucleus. In some places, not in the immediate vicinity of the nucleus, its resemblance to the milky way, as it appears to the naked eye, both as to its structure and in the number and disposition of the stars in it, is such, that the comparison conveys a tolerably correct idea of its appearance when seen under the most favorable circumstances.

The justice of this comparison received some additional confirmation on counting the number of stars visible in different fields of view. It was thought that, in the richest regions, two hundred to a single field was not an extravagant estimate.

The power employed being one hundred and three, having a field of view of twenty minutes, the *apparent* field subtended an angle of about thirty-four degrees. The portion of the milky way included in a circle of the same dimensions described about α Cygni contains about two hundred and ten stars, visible without telescopic aid. It should be noticed that the presence of these stars is no safe indication of resolution, since there is equal reason for supposing that we are viewing the nebula through a dense stellar stratum, which would produce the same impression on the eye.

The nebula h 51 is involved in the light of the great nebula. h 44 appears, under high powers, to be a coarse cluster of stars, the direction of the axis being determined apparently by three somewhat brighter than their companions; there is little doubt of a connection with the great nebula, by a continuation of the axis of h 44 in the south-following direction.

h 45, which is registered as "a very large space filled with nebulous matter," is far within the limits of the great nebula. No. 7 of the catalogue of "Extensive Diffused Nebulosities," published by Sir William Herschel in the *Philosophical Transactions* for 1811, is also a part of the great nebula.

No. 8 of the same catalogue lies so near to the southern boundary of the nebula, that, according to the dimensions assigned to it, it should also be considered as connected.

The most interesting feature of the nebula is the existence of the dark bands or canals before referred to. That which is nearest the nucleus is the longest and the most distinct. It commences somewhat abruptly near a group of small stars, in A. R. $0^{\text{h}} 32^{\text{m}} 36^{\text{s}}$ and Dec. $40^{\circ} 07'$; its breadth being about one minute and one half of arc. For about half a degree, to A. R. $0^{\text{h}} 34^{\text{m}} 10^{\text{s}}$, Dec. $40^{\circ} 30'$, it is marked with great uniformity; its sides being to all appearance perfectly straight, suddenly terminated, and slightly diverging. Soon after passing the parallel of the nucleus, it appears to bend towards the following side, becoming fainter and less regular; beyond the parallel of $40^{\circ} 50'$ it can no longer be traced with certainty.

The second commences at a point a few minutes north-preceding the first, and is there distant from it about four minutes of arc. It closely resembles its companion, excepting that, as it occurs in fainter light, it is less distinct, and is sooner lost after passing the nucleus.

The two are inclined to each other by an angle of about three degrees, their distance apart increasing towards the north. Their sides seem to have a common point of divergence.

Sir John Herschel, in his catalogue of nebulae published in the *Philosophical Transactions* for 1833, refers, with an expression of astonishment, to a structure evidently analogous to that just described, though on a scale greatly inferior, which occurs in *h* 1357 and 1376; engravings of both, faithfully representing the originals, accompany the catalogue. It may be noticed that these three most interesting objects lie almost precisely in a great circle of right ascension, which intersects the milky way at right angles.

The following table contains the right ascension and declination of the chief points of interest in the nebula. It should be observed, that, where the light is faint, the positions given are liable to a considerable degree of uncertainty.

	A.R. 1850.			Dec. 1850.	Remarks.
	h.	m.	s.		
1	0	30	50	+39 17	The axis may be traced to this point.
2	0	31	30	39 27	Light blends with the star-dust which fills the field ; the axis is about 5' broad and not distinguishable without attention.
3	0	31	55	39 38	Axis suddenly widens and becomes brighter.
4	0	32	12	39 45	Light brighter and unequally diffused, with dark openings ; many stars in clusters.
5	0	32	08	39 55	Suddenly much brighter. The peculiarity noticed in 4 is more strongly marked. The position given is that of a spot much brighter than any other part of the field.
6	0	32	15	39 58	Axis 12' broad and distinctly marked. The light is more evenly diffused, brighter and more nebulous in its character, especially on the following side.
7	0	34	30	40 00	Companion nebula <i>h</i> 51. It is certainly within the light of the great nebula ; in the field preceding it are multitudes of very small stars, on a ground of very evenly diffused, milky nebulosity.
8	0	32	36	40 07	Southern extremity of the inner canal.
9	0	31	40	40 10	Light is here unequally diffused. On the side following the axis, it falls away more rapidly than on that preceding.
10	0	33	40	40 15	The northern part of the field is brightest. Both canals are well seen in this parallel. The light is shaded off from them evenly on the preceding side.
11	0	33	15	40 20	Both canals beautifully distinct. The light between them is two thirds as bright as it is on the inner side of that which is nearest to the nucleus. Both large and small stars are very abundant in this parallel.

	A.R. 1850.			Dec. 1850.	Remarks.
	h.	m.	s.		
12	0	34	24	+40 26	The nucleus. The light shades off soonest on the following side.
13	0	35	00	40 36	The light is here broken up and unequal ; with numerous stars. The canals in this parallel begin to incline towards the following side.
14	0	32	00	40 36	Apparent continuation of <i>h</i> 44 in the south-following direction towards the great nebula.
15	0	36	40	40 36	A dark opening in the surrounding nebulosity. In and north of this parallel, the light is distributed with less regularity than heretofore ; and the outer canal is frequently interrupted.
16	0	35	40	40 50	The inner canal is not to be traced with certainty beyond this point.
17	0	34	36	40 53	Stars very numerous. The light shades off more gradually on the side following the axis than it does nearer the nucleus.
18	0	35	50	40 57	A ridge of light, or of stars, parallel to the axis, gives the impression of a continuation of the inner canal. Many small stars.
19	0	35	11	41 03	Light in decided bright knots, with dark openings, as in 4 and 5. Great numbers of stars. This is the position of <i>h</i> 45 ; there is no uncertainty with regard to its being a part of the great nebula.
20	0	38	12	41 20	Northern extremity of the axis.